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Design of P-V Based Pumping System

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Abstract : This paper presents design and analysis of a single phase induction motor drive using IGBTs at the inverter power stage with volts hertz control (V/f) in closed loop using ATMEGA32 as a controller.The power converter & the microcontroller unit (MCU) acts as an interface between the solar panel & the SPIM. The power converter is a H-bridge converter composed of four IGBT and for switching ON/OFF these IGBT's requires a driver circuit which are operated according to the SPWM technique controlled by the MCU. Mathematical analysis is carried out to demonstrate the feasibility of the proposed approach. Microcontroller (ATMEGA32) is used to generate the SPWM pulses for inverter to drive the 0.5 Hp, 1-phase Induction Motor.Detailed investigation of the project has been discussed below.

Keywords: Maximum power point tracking (MPPT), V/f method, Push pull type bridge inverter, Sinusoidal pulse width modulation (SPWM) technique.

I. INTRODUCTION

There are some areas across the country where electricity is not available & if available it is very erratic. Over this, the prices of electricity are rising inexorably day by day. To overcome such problems solar energy "mother of all renewable energy" is the only viable option which is not only cheaply available but also pollution free. The development of photovoltaic (PV) panels has made solar-powered pumps a reality. Solar panel is one of the ways to convert the solar energy into electrical energy but only in dc form. A solar panel is a set of solar photovoltaic modules electrically connected & mounted on a supporting structure [1]. The efficiency of a module determines the area of a module –an 8% efficient 230 watt module will have twice the area of a 16% efficient 230 watt module. In this discussion, MPPT technique has been utilized to extract the whole energy that the PV panels can generate depending on the environmental conditions including irradiation and temperature [2,3]. In this paper the whole system consists of a solar panel, h-Bridge inverter circuit, a SPIM, a microcontroller unit. Of course other accessories like current sensor, attenuator circuit etc are also needed. The PV solar array generates electrical power as a direct current & to run the SPIM, a push pull type H-bridge inverter circuit composed of IGBT has been implemented. For turning ON & OFF IGBT, pulses are applied to the gate terminals of each IGBT through the driver circuit generated by the MCU.The Pulses generated by the MCU is based on SPWM technique in which the reference signal is compared with a triangular carrier signal (1KHz).The pulses are generated each time the magnitude of the carrier wave signal is greater than the magnitude of reference signal & vice versa & so does the turning ON & OFF of IGBT's are controlled. For controlling the speed of the motor, V/f method has been implemented. In this method the ratio of voltage applied to the motor & the operating frequency is maintained constant so that the torque produced will remain constant and at the same time variable speed is obtained which in turn can maintain the delivery head constant but at a variable discharge rate respectively[4].

II. PROPOSED SCHEME

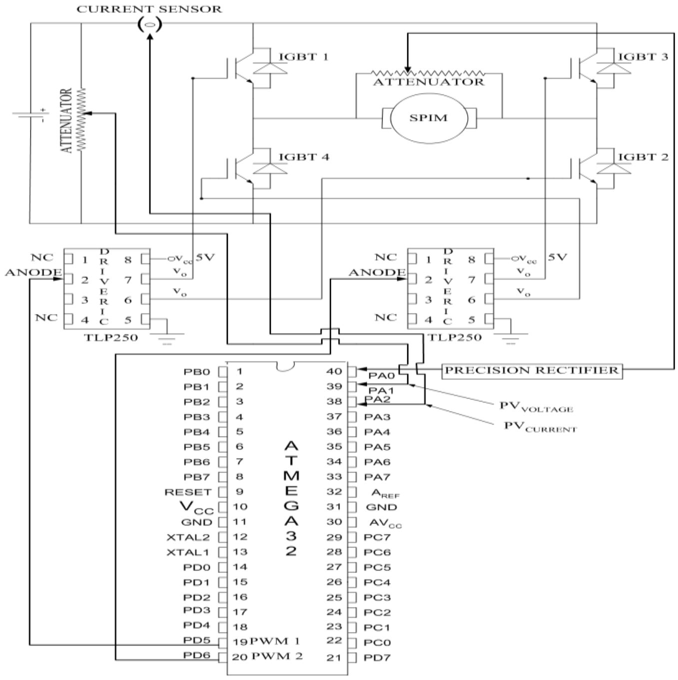


Fig (a) proposed scheme

III. SOLAR PANEL & MPPT

Solar photovoltaic panels are being increasingly used for converting the solar energy into electrical form. In addition to this, MPPT technique has been implemented to abstract maximum power from the panel & here the Perturb & observe method are being used.

In this method, the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is called the Perturb and

observes method and is most common, although this method can result in oscillations of power output. Perturb and observe is the most commonly used MPPT method due to its ease of implementation.This process works by increasing or decreasing the duty cycle of a DC to AC converter and observing its impact on the array output power. This later is compared to its previous value and according to the result of the comparison, the sign of “slope”, which is a program variable is either complemented or remains unchanged. Then, the SPWM output duty cycle is changed accordingly [2].

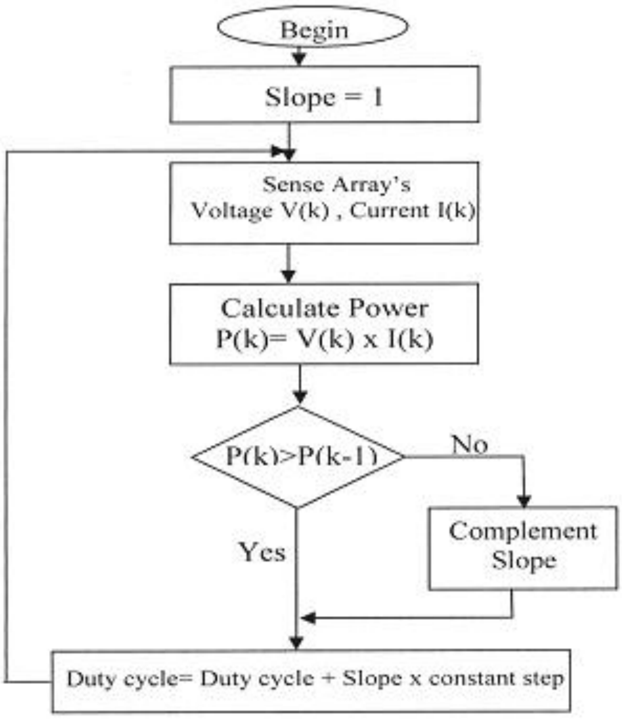


Fig (b) Flow charts for the Perturb & observe method

IV. MATHEMATICAL ANALYSIS OF V/F METHOD FOR SPEED CONTROL OF INDUCTION MOTOR

The base speed of an induction motor is given by

$$N = \frac{120 * f}{P} \quad \Rightarrow \quad N \propto f \qquad (1)$$

The torque developed in an induction motor is given by

$$T = \frac{K * \varphi * s * E_2^2 * R_2^2}{\sqrt{R_2^2 + (sX_2)^2}} \quad \Rightarrow \quad T \propto \varphi \qquad (2)$$

Since an transformer is equivalent to an induction motor with rotating secondary

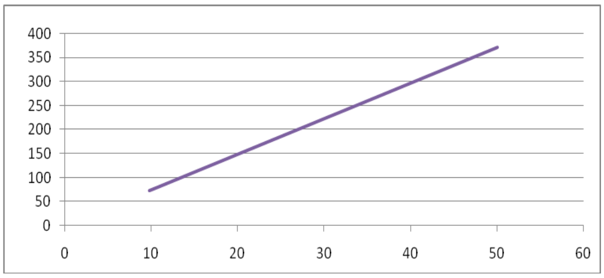
$$V \cong E = 4.44 * f * \varphi_m * N \quad \Rightarrow \quad \varphi_m \propto \left(\frac{V}{f}\right) \qquad (3)$$

From equations 1, 2&3, it is clear that by varying the values of voltage and frequency but maintaining their ratio constant, it is possible to maintain the torque developed by the motor constant at a variable speed & variable power output [5, 6, 7,8].

Voltage(Volts)	Frequency (Hz)	v/f ratio	Speed (rad/sec)	Power (Watts)
230	50	4.6	157	372
220	48	4.6	150	356
210	46	4.6	143	340
200	43	4.6	137	324

Table(i)

From the table (i) it is clear that by varying the values of voltage applied to the motor and the operating frequency but maintaining the v/f ratio constant, as frequency changes power also changes proportionately as shown in the graph below.



Fig(c) Speed torque characteristics with v/f control

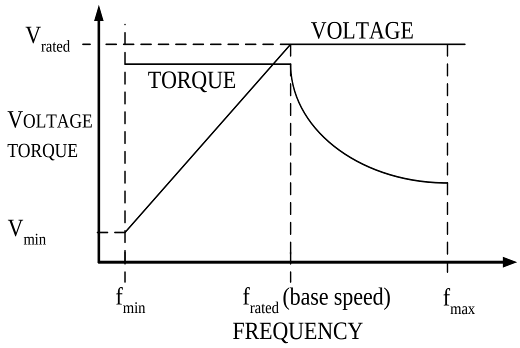
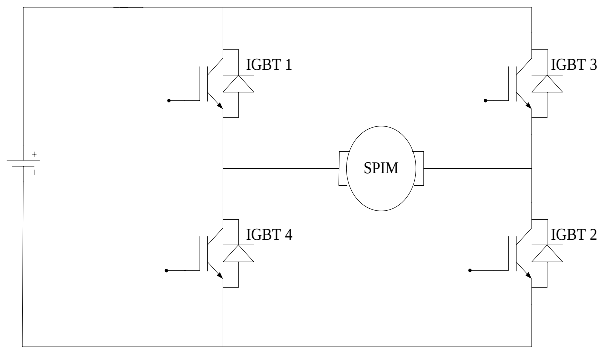


Fig (d) Torque speed characteristics of induction motor with V/f control

In v/f method for speed control of induction motor, the frequency can be increased beyond the rated value but voltage can’t be increased beyond rated value due to insulation problem. The motor can be driven above base speed by increasing the frequency beyond rated value but the torque will get reduced as the torque governing factors such as friction & windage loss increase significantly above base speed. Hence the torque curve becomes non linear with respect to speed or frequency [9].

V. H-BRIDGE INVERTER



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An **H bridge** is an electronic circuit that enables a voltage to be applied across a load in either direction. The term H Bridge is derived from the typical graphical representation of such a circuit. An H bridge is built with four switches as shown above in the figure. When the IGBT1, IGBT2 are closed and IGBT3, IGBT4 are open a positive voltage will be applied across the motor. By opening IGBT1, IGBT2 and closing IGBT3, IGBT4 switches, this voltage is reversed, thus allowing alternating voltage to be applied to the induction motor. Using the nomenclature above, the IGBT1 and IGBT4 should never be closed at the same time, as this would cause a short circuit on the input voltage source. The same applies to the switches IGBT2 and IGBT3. This condition is known as shoot-through. The H-Bridge circuit that are used consists of four power IGBT's which act as fast switching device. This H-bridge uses IGBT's for many reason like low on state forward voltage drop & is preferable when switching frequency is less than 20 KHz & operating voltage is above 200V.The IGBT used for the H-Bridge inverter is H20R1203. It is a three pin IC with maximum ratings of 1200V and 40A.

VI. SINUSOIDAL PULSE WIDTH MODULATION (SPWM)

PWM inverters are gradually taking over other types of inverters in industrial applications. PWM techniques are characterized by constant amplitude pulses. The width of these Pulses is, however modulated to obtain inverter output voltage control and to reduce its Harmonic content.

In this modulation the triangular waveform is compared with sinusoidal waveform. The inputs to the comparator are Vc and Vt. The output of the comparator is high when the magnitude of the sinusoidal voltage is greater than the magnitude of triangular voltage. It can be seen that the output voltage has a train of pulses of unequal width. The width is maximum for the central pulse and it decreases on either side. The width of the pulse varies sinusoidally so the harmonic content is least as compare to other mode [10].

VII. MICROCONTROLLER

In this project, microcontroller (ATMEGA32) has been used for generating the pulses so that the switching operation of the IGBT's can be controlled which is based upon SPWM technique through the driver circuit (TLP250).the driver circuit is needed for amplifying the signals generating from the microcontroller. The voltage & current feedback is taken from the solar panel so that the panel can be operated to deliver maximum power. Feedback is also taken from voltage across the SPIM through an attenuator circuit & accordingly the frequency is changed with the help of programming in such a way that the ratio of voltage & frequency will remains constant throughout the speed range & thus the V/f method for speed control of induction motor is implemented.

VIII. SIMULATION MODEL

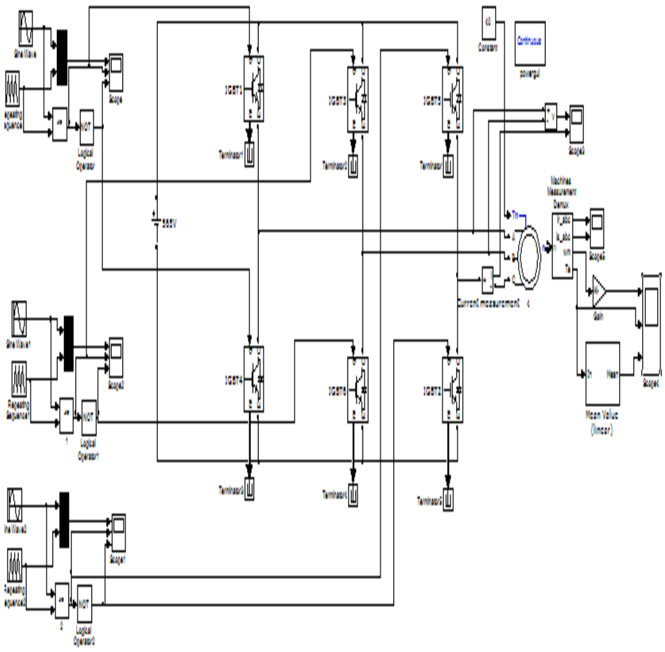

Fig (e) Simulation model of V/f method for speed control of induction motor.

IX. SIMULATION RESULTS

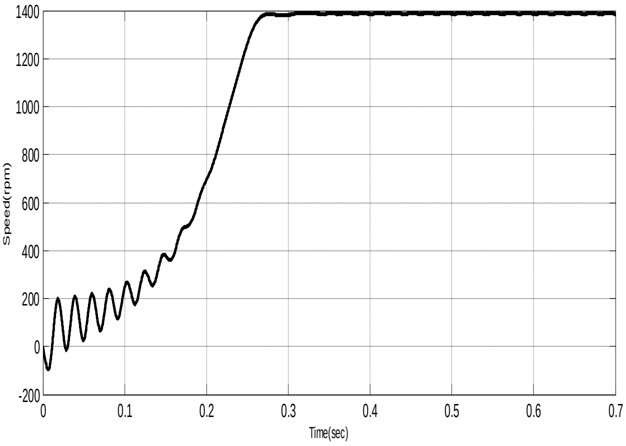

Fig (f) Speed of the induction motor

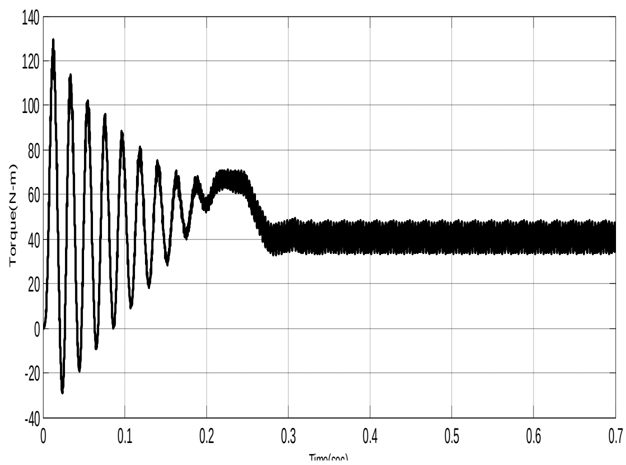

Fig (g) Torque developed by the induction motor

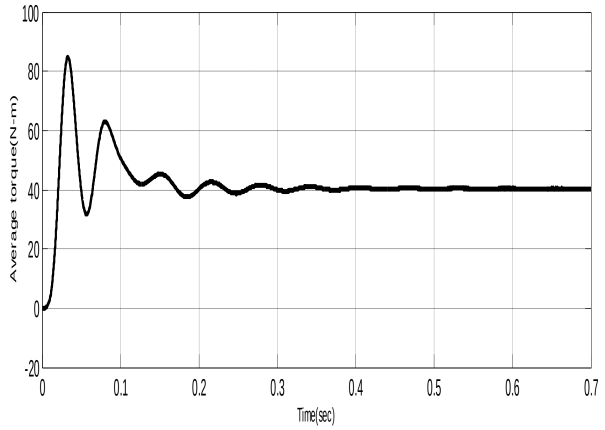

Fig (h) Average torque developed by the induction motor

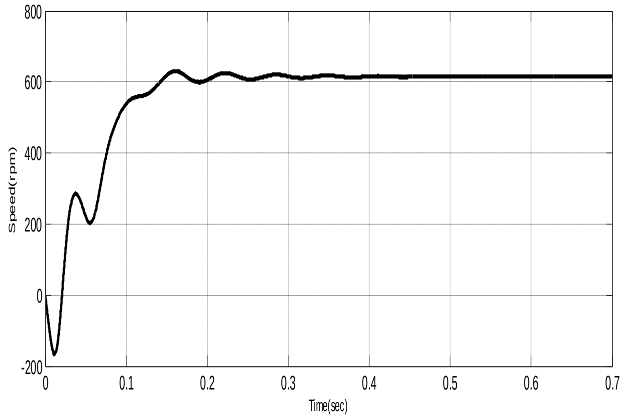

Fig (i) Speed of the induction motor

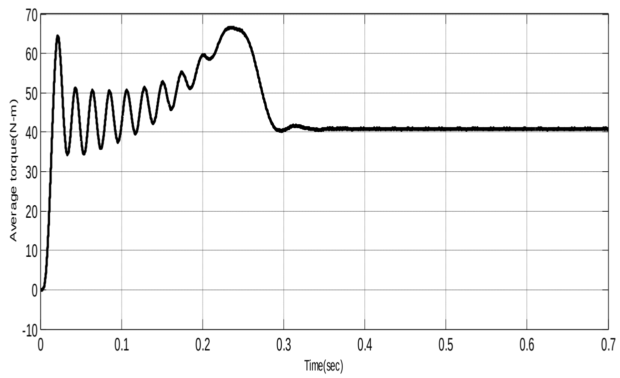

Fig (j) Average torque developed by the induction motor

Figures (f), (g), (h) shows the simulation results obtained when the applied voltage & frequency are 400V &50Hz respectively.
Figures (i), (j) shows the simulation results obtained when the applied voltage & frequency are 200V & 25Hz respectively.

X. CONCLUSION

From the above analysis it can be concluded that the torque developed by the motor remains the same at varying speed if the ratio of V/f remains the same.

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